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Childhood vaccination in Kenya: socioeconomic determinants and disparities among the Somali ethnic community

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Abstract

Objectives Kenya has a significant refugee population, including large numbers of Somali migrants. This study examines the vaccination status of Kenyan children and sociodemographic predictors of vaccination, including Somali ethnicity.

Methods Using the 2014 Kenyan Demographic and Health Survey, we calculated the proportion of non-vaccinated, under-vaccinated, and fully vaccinated children, defining full vaccination as one dose Bacille Calmette-Guerin, three doses polio, three doses pentavalent, and one dose measles. We assessed associations among various factors and vaccination status using multinomial logistic regression and explored the effect of Somali ethnicity through interaction analysis.

Results The study sample comprised 4052 children aged 12–23 months, with 79.4% fully, 19.0% under-, and 1.6% non-vaccinated. Among Somalis, 61.9% were fully, 28.7% under-, and 9.4% non-vaccinated. Somalis had significantly greater odds of under- and non-vaccination than the Kikuyu ethnic group. Wealth and birth setting were associated with immunization status for Somalis and non-Somalis.

Conclusions Disparities persist in pediatric vaccinations in Kenya, with Somali children more likely than non-Somalis to be under-vaccinated. Health inequalities among migrants and ethnic communities in Kenya should be addressed.

Keywords Pediatric vaccination · Vaccination coverage · Somali · Kenya · Health disparities · Migrant health

Introduction

The Kenyan Ministry of Health's focus in recent years on reducing childhood morbidity and mortality has had encouraging results, with under-five mortality declining 36%, from 115 per 1000 live births in 2003 to 74 per 1000 in 2008, although still short of the Sustainable Development Goal (SDG) threshold for sub-Saharan Africa (UN 2017; UNICEF 2015a). Kenya's Expanded Program on Immunization (EPI) has been a key component of the government's efforts to reduce childhood mortality, providing six different vaccines comprising 10 antigens free to children nationwide: one dose Bacillus Calmette-Guérin (BCG), four doses oral polio vaccine (OPV), three doses pentavalent (containing diphtheria-tetanus-pertussis [DTP]), *Haemophilus influenzae* type b [Hib], and hepatitis b [HBV]), one dose measles-containing vaccine (MCV), three doses pneumococcal conjugate vaccine (PCV), and two doses rotavirus vaccine (Gibson et al. 2015; Haji et al. 2016; Ministry of Public Health 2013). PCV and rotavirus are newer introductions, added to the EPI in 2011 and 2014, respectively, and Yellow Fever vaccines are given only in two endemic areas: Baringo and Elgeyo Marakwet (Ministry of Public Health 2013). Despite Kenya's focus on childhood immunization, below-target coverage levels for OPV (77%) and MCV (74%) persist, with ongoing transmission of measles continuing at low levels (Masresh et al. 2017; Onsomu et al. 2015; UNICEF 2015b).

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Vaccination coverage is notably low in certain demographic groups, particularly among the Somali ethnic minority. Kenya's Somali population encompasses a range of individuals, from those living in the country for generations, to more recent refugees living in the Dadaab refugee camp, primarily in the North Eastern region of Kenya (Polonsky et al. 2013). Civil unrest and military conflict in neighboring countries, notably Somalia, have contributed to Kenya's burgeoning Somali refugee population, posing additional challenges for immunizing children, as refugees may lack familiarity with customs, are harder to reach, and may either be reluctant to use governmental services or encounter societal discrimination preventing access, all of which may impede vaccine uptake (UNHCR 2016). Previous literature has identified several barriers to vaccination in East African countries, including low maternal education, (Canavan et al. 2014; Gibson et al. 2015; Kawakatsu et al. 2015; Onsomu et al. 2015; Soura et al. 2015) poverty, (Canavan et al. 2014; Kawakatsu et al. 2015; Onsomu et al. 2015) traditional or Muslim religion, (Canavan et al. 2014; Onsomu et al. 2015; Soura et al. 2015) non-institutional delivery, (Canavan et al. 2014) residence-type, (Delrieu et al. 2015; Kawakatsu et al. 2015; Soura et al. 2015), and lack of antenatal care (Gibson et al. 2015). Somalis in Kenya occupy a vulnerable position vis-à-vis many of these barriers, which merits a more in-depth investigation to clarify resultant impacts on vaccination uptake and coverage levels.

Most prior studies in East Africa have been limited in only examining a narrow selection of predictors or were restricted geographically to specific provinces, towns, or facilities, resulting in non-representative samples (Canavan et al. 2014; Gibson et al. 2015; Kawakatsu et al. 2015; Soura et al. 2015). Similar to other African nations, Kenya faces multiple and varied challenges in ensuring a fully immunized childhood population given an insufficient public health infrastructure and rapidly expanding population, including an annual birth cohort of over 1.5 million, among the top 10% globally (UNICEF 2013). This study explored the demographic, socioeconomic, and health-related predictors of non-, under-, and full vaccination status in Kenya, with special focus on health disparities among the Somali ethnic group. While studies in Ethiopia have found Somalis with reduced odds of full vaccination (Lakew et al. 2015; Mohamud et al. 2014), there is a research gap regarding the immunization status of Somalis in Kenya. Additionally, prior studies have explored binary classifications of vaccination: either fully/non-fully vaccinated (Kawakatsu et al. 2015) or based upon individual vaccine-receipt (Onsomu et al. 2015), but rarely explore non-vaccination, under-vaccination, and full vaccination as an outcome.

This study's objectives were to estimate full-, under-, and non-vaccination prevalence rates in Kenya, examine sociodemographic predictors of full vaccination, and explore any interaction effect with Somali ethnicity. Findings can inform programmatic interventions and efforts to meet the Sustainable Development Goals of universal health coverage, including vaccines for all, and the reduction of under-five mortality rates to 25 per 1000 by 2030 (Alkema et al. 2016; Macharia et al. 2015; Tao et al. 2013; UNICEF 2012).

Methods

Study population and sample

The Demographic and Health Survey (DHS) program, funded by USAID, has facilitated the administration of more than 300 surveys in over 90 countries since its inception in 1984. The DHS is a widely used, standardized, cross-sectional survey producing comparable, nationally representative data on fertility, family planning, maternal and child health (including immunizations), and health systems functioning across the globe (Pullum and Staveteig 2017). The most recent DHS in Kenya was carried out in 2014 using a two-stage stratified sampling design with eight regions and 92 sampling strata encompassing all counties, including rural and urban areas. The primary sampling units (PSUs) were census enumeration areas and were selected with a probability proportional to size methodology using populations from the 2009 census. Within each of the 1612 PSUs, 25 households were selected. The Kenya National Bureau of Statistics conducted in-person interviews with all eligible women aged 15–49 years in the household about reproductive health, maternal care, childhood immunizations, and childcare from May–October 2014. The Kenya DHS dataset is publically available. A total of 39,679 households were selected for the original DHS sample, of which 36,430 were successfully interviewed, yielding a 99% response rate (Masters et al. 2018). Specific inclusion criteria for our analysis required mothers of children aged 12–23 months (n = 4052). Only one child per mother was included: the oldest child per mother within the eligible age category (Kenya National Bureau of Statistics et al. 2015).

Derived variables and measurement

The primary outcome was a three-way category comprising full vaccination, under-vaccination, and non-vaccination. Full vaccination was defined as receipt of one dose BCG, one dose MCV, three doses pentavalent, and at least three doses of OPV. PCV and rotavirus vaccines were not

included in the full vaccination analysis due to their recent introduction in Kenya's EPI, which likely has not allowed for adequate time to reach representative coverage levels. Respondents were asked whether they had a vaccination card for their child, and if they were unable to produce a health card or if the card had missing information, they were asked to recall whether their child received each vaccine, and the number of doses. Successful receipt of a vaccine was defined as a verified vaccination record via card or recall. Under-vaccination was defined as receipt of at least one EPI dose, but fewer than all the recommended doses. Non-vaccination was defined as not having received any doses of any vaccines. Birth setting was determined by combining birth assistance and delivery place, resulting in five categories: (1) public institution, (2) private institution, (3) non-institutional (home/other) with a trained attendant (doctor/nurse/midwife), (4) non-institutional with a traditional birth attendant (lay community member who assists with childbirth), and (5) non-institutional with no attendant (relative/friend/other/no assistance).

Because of small sample sizes for certain religions, we collapsed "No Religion" into "Other". Similarly, due to small sample sizes for some of the 23 Ethnic groups represented in the Kenyan DHS, we collapsed Embu, Maasai, Meru, Taita/Taveta, Turkana, Samburu, Pokomo, Iteso, Boran, Gabbra, Kuria, Orma, Mbere, and Rendille ethnic groups into "Other". The Kalenjin, Kamba, Kikuyu, Kisii, Luhya, Luo, Mijikenda/Swahili, and Somali ethnic groups were retained for analysis. Antenatal care was collapsed into 0, 1–3, and 4 or more visits, following WHO recommendations (The Partnership for Maternal, Newborn, and Child Health 2006).

Statistical analysis

The distribution of socioeconomic, demographic, and clinical factors is presented using descriptive statistics. Variables were chosen based on an a priori consideration of important predictors (Canavan et al. 2014; Lakew et al. 2015; Rossi 2015). In addition to derived variables, child sex, region of residence, place of residence (urban, rural), wealth index, and health card possession were included in the analysis. The associations between risk or preventive factors and under- and non-vaccination were assessed in a multinomial logistic regression. The distinction between predictors for vaccination for Somalis and non-Somalis was assessed using an interaction analysis, where all explanatory variables in the logistic interaction analysis were forced into an interaction with a dichotomous variable representing Somali/non-Somali ethnicity. For ease of interpretation, this analysis has been stratified, with the predictors listed separately for Somalis and non-Somalis. All descriptive and analytical statistics followed standard survey procedures. Analyses included weights based on the female head of house, so that the findings are representative of the national circumstances of women and children in Kenya. Sensitivity analyses were conducted without DHS weights for inferential statistics yielding no significant differences. PSUs were specified as the clusters and urbanicity as the stratum. Variance was estimated through the Taylor series method, with missing values analyzed as not missing completely at random by specifying the non-missing values as a domain of the entire population (utilizing the NOMCAR option). Significance was assessed at an $\alpha = 0.05$, and all analyses were conducted in SAS version 9.4 (SAS Institute, Cary, NC, USA) (Masters et al. 2018).

Results

A total of 31,079 women aged 15–49 years were interviewed using the Kenya DHS full-woman questionnaire. These mothers answered questions about 17,055 children, of whom 4052 (23.76%) were aged 12–23 months and were included in the study sample.

Demographic covariates

Demographic covariates are reported in Table 1 for those aged 12–23 months. Children resided in all eight regions in Kenya, with the largest percentage from the Rift Valley region, and the largest ethnic groups represented were Kikuyu and Luhya. Somalis represented 7.8% of the sampled population. Wealth index was approximately divided into quantiles for the entire survey sample, and mothers of 6.9% of those aged 12–23 months reported that they did not have a health card for their child. Nearly half of children (45.8%) were born or attended to in a public institution, followed by non-institutional (36.8%) and private institutional births (17.4%). Non-institutional births were almost evenly divided between those with a traditional attendant present and those with no attendant, though only 1.0% of children had a non-institutional birth with a trained attendant. The majority (70.7%) of the full sample was Protestant/Other Christian, with 17.9% Roman Catholic and 8.6% Muslim; however, all Somalis were Muslim. Additionally, Kenyan Somalis were predominantly (83.1%) from the North Eastern region bordering Somalia ($p < 0.001$), 64.8% were in the poorest wealth quintile ($p < 0.001$), and nearly a quarter (24.5%) did not have a health card or no longer had one ($p < 0.001$). Finally, most Somalis (56.3%) in the sample had non-institutional births with a traditional attendant, followed by public institutional (23.2%) and private institutional births

Table 1 Demographic covariates for analysis of under- and non-vaccination among subset of children aged 12–23 months, Kenya Demographic and Health Survey IV, 2014

Demographic factors	n	Full sample % (95% CI)	Non-Somalis % (95% CI)	Somalis % (95% CI)	p value*
Sex of child	4052				0.534
Male	2099	52.0 (49.9, 54.2)	52.0 (49.8, 54.1)	54.2 (48.2, 60.2)	
Female	1953	48.0 (45.8, 50.1)	48.1 (45.9, 50.2)	45.8 (39.8, 51.8)	
Region	4052				< 0.001
Coast	517	10.3 (9.1, 11.6)	10.6 (9.3, 11.9)	4.1 (2.6, 5.7)	
North Eastern	295	3.2 (2.5, 3.9)	0.1 (0.0, 0.1)	83.1 (79.4, 86.8)	
Eastern	585	11.4 (10.1, 12.7)	11.9 (10.5, 13.2)	0.6 (0.0, 1.1)	
Central	291	9.6 (8.5, 10.8)	10.0 (8.8, 11.2)	–	
Rift valley	1314	28.7 (26.6, 30.8)	29.7 (27.5, 31.8)	4.1 (3.4, 4.8)	
Western	364	11.1 (9.4, 12.8)	11.5 (9.8, 13.3)	0.4 (0.4, 0.5)	
Nyanza	580	14.6 (13.1, 16.1)	15.2 (13.6, 16.7)	0.8 (0.6, 0.9)	
Nairobi	106	11.0 (9.0, 13.1)	11.2 (9.1, 13.3)	6.9 (4.6, 9.2)	
Place of residence	4052				0.735
Urban	1261	35.2 (33.0, 37.5)	35.2 (32.8, 37.5)	37.0 (29.5, 44.6)	
Rural	2791	64.8 (62.5, 67.0)	64.9 (62.5, 67.2)	63.0 (55.4, 70.5)	
Wealth Index	4052				< 0.001
Poorest	1436	24.9 (22.9, 26.9)	23.3 (21.3, 25.3)	64.8 (57.3, 72.3)	
Poorer	853	20.3 (18.6, 21.9)	20.9 (19.2, 22.7)	3.3 (1.3, 5.3)	
Middle	647	17.7 (15.9, 19.5)	18.2 (16.4, 20.0)	4.3 (1.4, 7.1)	
Richer	598	17.6 (15.7, 19.5)	18.0 (16.1, 20.0)	7.6 (3.7, 11.5)	
Richest	518	19.6 (17.2, 22.0)	19.6 (17.1, 22.0)	20.0 (14.8, 25.1)	
Religion	4045				
Roman catholic	758	17.9 (16.1, 19.6)	18.6 (16.8, 20.4)	–	
Protestant/other christian	2485	70.7 (68.6, 72.7)	73.4 (71.5, 75.4)	–	
Muslim	680	8.6 (7.4, 9.9)	5.0 (4.1, 6.0)	100	
Other	122	2.8 (2.2, 3.5)	2.9 (2.2, 3.6)	–	
Received antenatal care (ANC)	3842				< 0.001
No ANC visits	215	3.5 (2.8, 4.1)	2.9 (2.2, 3.5)	18.9 (13.2, 24.6)	
1–3 ANC visits	1516	37.9 (35.9, 40.0)	37.9 (35.8, 40.0)	39.4 (32.9, 45.9)	
4 or more ANC visits	2111	58.6 (56.5, 60.7)	59.2 (57.1, 61.4)	41.7 (33.7, 49.7)	
Has a health card	4049				< 0.001
No card	87	1.1 (0.8, 1.5)	0.5 (0.2, 0.7)	17.2 (10.3, 24.0)	
Yes, seen	3047	74.8 (72.7, 76.8)	75.6 (73.5, 77.7)	53.4 (45.7, 61.2)	
Yes, not seen	688	18.3 (16.5, 20.1)	18.1 (16.3, 20.0)	22.1 (15.2, 29.0)	
No longer has card	227	5.8 (4.8, 6.9)	5.8 (4.7, 6.8)	7.3 (4.0, 10.6)	
Birth setting	4044				< 0.001
Public institution	1735	45.8 (43.4, 48.1)	46.6 (44.2, 49.1)	23.1 (16.9, 29.4)	
Private institution	514	17.4 (15.5, 19.3)	17.5 (15.6, 19.3)	15.8 (11.7, 19.8)	
Non-institutional with trained attendant	56	1.0 (0.7, 1.4)	0.9 (0.6, 1.3)	3.6 (1.1, 6.0)	
Non-institutional with traditional attendant	997	18.9 (17.2, 20.6)	17.4 (15.7, 19.2)	56.3 (47.4, 65.2)	
Non-institutional with no attendant	742	16.9 (15.3, 18.5)	17.5 (15.8, 19.2)	1.2 (0.1, 2.4)	
Ethnicity	4051				
Kalenjin	616	13.3 (11.8, 14.9)	13.9 (12.2, 15.5)	–	
Kamba	301	9.6 (8.2, 11.0)	10.0 (8.5, 11.5)	–	
Kikuya	477	17.5 (15.4, 19.7)	18.2 (16.0, 20.5)	–	
Kisii	195	5.3 (4.2, 6.4)	5.5 (4.3, 6.7)	–	
Luhya	449	15.4 (13.3, 17.6)	16.0 (13.8, 18.2)	–	
Luo	436	12.5 (11.1, 13.9)	13.0 (11.5, 14.5)	–	

Table 1 (continued)

Demographic factors	n	Full sample % (95% CI)	Non-Somalis % (95% CI)	Somalis % (95% CI)	p value*
Mijikenda/Swahili	236	5.9 (5.0, 6.9)	6.2 (5.2, 7.2)	–	
Somali	316	3.8 (3.0, 4.6)	–	100	
Other	1025	16.6 (14.8, 18.4)	17.3 (15.4, 19.2)	–	

ANC Antenatal care

*Modified Rao–Scott Chi-square test performed between Somalis and non-Somalis

(15.8%), a significantly different distribution than for non-Somalis with $p < 0.001$.

Percentage of non-, under-, and fully immunized children

Table 2 shows the percentage of children by vaccination status and Somali ethnicity. For children aged 12–23 months, 79.4% were fully vaccinated with all recommended EPI vaccines, 19.0% were under-vaccinated, and 1.6% were non-vaccinated. When the sample was restricted to report the vaccination coverage among Somalis specifically, the fully vaccinated percentage was lower, 61.9%, and more individuals were under- (28.7%) and non-vaccinated (9.4%). This trend held true for each individual vaccine: For the full sample, 89.9% of children received three doses of pentavalent, but only 79.9% of Somalis did. For the OPV series, vaccination coverage was 91.8% for all children and 78.4% for Somalis. BCG coverage was the highest, while measles was the lowest. The disproportionate representation of Somalis in non-vaccinated and under-vaccinated children is shown in Fig. 1; nearly half (47.6%) of the non-vaccinated children in were Somali, though only 7.8% of children aged 12–23 months in the study sample were Somali.

Table 2 Percentage of non-, under-, and fully vaccinated Kenyan children aged 12–23 months with Expanded Program on Immunization (EPI) vaccines, Kenya Demographic and Health Survey IV, 2014

	Non-vaccinated % (95% CI)	Under-vaccinated % (95% CI)	Fully vaccinated % (95% CI)	p value*
Total population				
Complete series**	1.6 (1, 2.3)	19.0 (17.3, 20.6)	79.4 (77.7, 81)	
Pentavalent series	2.5 (1.8, 3.2)	7.6 (6.4, 8.9)	89.9 (88.5, 91.2)	
OPV series	1.8 (1.2, 2.5)	6.3 (5.4, 7.3)	91.8 (90.7, 93)	
BCG	3.3 (2.6, 4.1)	N/A	96.7 (95.9, 97.4)	
Measles	12.9 (11.6, 14.2)	N/A	87.1 (85.8, 88.4)	
Somalis				
Complete series	9.4 (5.5, 13.2)	28.7 (22.3, 35.1)	61.9 (55.6, 68.2)	< 0.001
Pentavalent series	11.0 (6.7, 15.3)	9.0 (4.3, 13.7)	79.9 (73.5, 86.3)	< 0.001
OPV series	9.6 (5.8, 13.4)	12.0 (7.1, 16.8)	78.4 (72.8, 84.1)	< 0.001
BCG	14.5 (10.5, 18.6)	N/A	85.5 (81.4, 89.5)	< 0.001
Measles	25.5 (18.8, 32.3)	N/A	74.5 (67.7, 81.2)	< 0.001
Non-Somalis				
Complete series	1.3 (0.7, 2)	18.6 (16.9, 20.3)	80.1 (78.4, 81.8)	< 0.001
Pentavalent series	2.1 (1.4, 2.9)	7.6 (6.4, 8.8)	90.3 (88.9, 91.6)	< 0.001
OPV series	1.5 (0.9, 2.2)	6.1 (5.1, 7.1)	92.3 (91.2, 93.5)	< 0.001
BCG	2.9 (2.1, 3.7)	N/A	97.1 (96.3, 97.9)	< 0.001
Measles	12.4 (11.1, 13.7)	N/A	87.6 (86.3, 88.9)	< 0.001

*Rao–Scott test of significance between Somalis and non-Somalis

**Complete series (Received Bacille Calmette-Guérin (BCG), Measles, 3 doses pentavalent vaccine (diphtheria-tetanus-pertussis (DTP), Haemophilus influenzae type B (Hib), and hepatitis B), 3 doses oral polio vaccine (OPV))
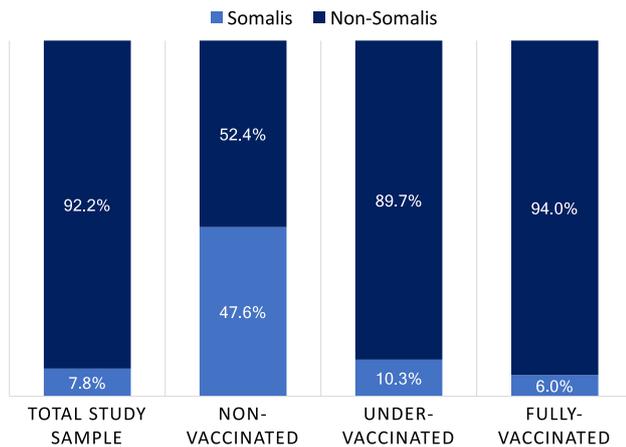
Fig. 1 Percentage of Kenyan Somalis aged 12–23 months by vaccination status, Kenya Demographic and Health Survey IV, 2014

Multinomial logistic model

Child's sex, child's age, respondent's region of residence (rural/urban), wealth index, ethnicity, religion, and birth setting were examined as predictors for full immunization status via multinomial logistic regression to correspond with common predictors utilized in the literature (Table 3). Birth setting, ethnicity, and wealth index were significant. The odds ratios revealed a general trend toward reduced risk of non-vaccination and under-vaccination with increasing wealth index, though a threshold effect was observed between the two richest indices. Relative to the Kikuyu ethnic group in Kenya, those of Somali ethnicity had markedly increased odds of non-vaccination (AOR 59.42) and under-vaccination (AOR 2.21) compared to full vaccination, the reference outcome. This effect was further explored by an interaction analysis (Table 4) of predictors among Somalis compared to non-Somalis (representing the majority of the sample and taken to be representative of the Kenyan population, excluding the Somali ethnic group).

Interaction analysis among Somalis and non-Somalis for full vaccination

Logistic interaction analysis (Table 4) among Somalis and non-Somalis revealed that rural setting significantly increased the odds of full vaccination among non-Somalis (AOR 1.2) but decreased the odds of full vaccination among Somalis (AOR 0.41) compared with urban setting. Wealth index had a significant interaction with Somali ethnicity and showed a trend among non-Somalis, with the poorest quintile having significantly lower odds of full vaccination: AOR 0.48, and the two richest quintiles having higher odds of full vaccination, whereas no trend was observed among Somalis. Birth setting also had a significant interaction p value in both Somalis and non-Somalis

whereby non-institutional births with no attendant correlated with lower odds of full vaccination, though the effect was more pronounced for Somalis than non-Somalis. A similar finding was observed for non-institutional births with a traditional attendant, though non-Somalis had more marked decreased odds of full vaccination.

Discussion

While Kenya registered a significant decrease in childhood mortality of nearly 50% between 2003 and 2014 (Kenya National Bureau of Statistics et al. 2015; Onsomu et al. 2015), VPDs continue to contribute disproportionately to child death. This study revealed that only three quarters of Kenyan children were fully vaccinated with all EPI recommended vaccines, well below the Ministry of Health's 2014 goal of 88% coverage (Ministry of Public Health 2013). Additionally, coverage of Penta3, OPV3, and measles were all below national target levels (90%), indicating suboptimal immunization systems performance, and a level of coverage insufficient to interrupt and control endemic transmission among children (Ministry of Public Health 2013). Persistently low childhood vaccination levels of this magnitude clearly call for increased efforts and resources to improve vaccine uptake and coverage.

Previous studies in Africa have shown differences in vaccination by ethnic group, with minority populations experiencing a lower likelihood of full vaccination (Lakew et al. 2015; Mohamud et al. 2014; Rossi 2015). Kenya is home to many ethnic groups, but ethnicity was not found to be strongly associated with non- and under-vaccination among ethnic minorities with the exception of Somalis, who had strikingly increased odds of non- and under-vaccination versus Kikuyu, the largest ethnic group in the sample. It is important to note that the Kenyan Somalis predominantly live in the North Eastern region of Kenya, which houses over three million Somalis. This region is also home to the Dadaab refugee camp, the world's largest refugee camp, established in 1991 with almost half a million residents (Polonsky et al. 2013). Somalia has been ravaged by civil wars, drought, and famine over the course of several decades, leading to a displacement of a significant portion of the population. Kenya houses more Somalian refugees, now numbering over 300,000, than any other neighboring East African country (UNHCR 2016). The Dadaab camp has witnessed measles outbreaks due to low vaccination and high susceptibility among Somali migrants, with the largest outbreak occurring in 2011, comprising 1370 cases and 32 deaths following a mass influx of refugees due to famine (Navarro-Colorado et al. 2011).

Table 3 Multinomial logistic model odds ratios for non- and under-vaccinated versus fully vaccinated status for Kenyan children aged 12–23 months, Kenya Demographic and Health Survey IV, 2014

Covariate	Non-vaccinated OR (95% CI)	Under-vaccinated OR (95% CI)	p value*
Child sex (female vs. male)	1.87 (0.84, 4.14)	0.91 (0.74, 1.12)	0.149
Rural versus urban dweller	0.74 (0.21, 2.66)	0.73 (0.55, 0.95)	0.061
Respondent's wealth index			< 0.001
Poorest	2.89 (0.59, 14.17)	1.82 (1.29, 2.55)	
Poorer	0.79 (0.13, 4.90)	1.08 (0.74, 1.56)	
Middle	Ref	Ref	
Richer	0.22 (0.04, 1.24)	0.75 (0.49, 1.13)	
Richest	0.81 (0.16, 4.17)	0.75 (0.44, 1.27)	
Respondent ethnicity			< 0.001
Kikuyu	Ref	Ref	
Kalenjin	1.08 (0.21, 5.66)	1.47 (0.90, 2.39)	
Kamba	0.29 (0.03, 3.22)	0.88 (0.47, 1.63)	
Kisii	< 0.001	0.82 (0.43, 1.58)	
Luhya	1.13 (0.14, 9.05)	1.34 (0.78, 2.32)	
Luo	0.76 (0.14, 4.20)	2.01 (1.19, 3.41)	
Mijikenda/Swahili	1.33 (0.1, 17.57)	1.21 (0.63, 2.31)	
Somali	59.42 (3.19, > 999)	2.21 (1.09, 4.47)	
Other	0.56 (0.11, 2.73)	1.54 (0.94, 2.53)	
Respondent religion			0.131
Protestant/other christian	Ref	Ref	
Muslim	0.05 (0.00, 0.62)	0.81 (0.50, 1.33)	
Roman catholic	0.41 (0.16, 1.04)	0.96 (0.70, 1.30)	
Other	0.18 (0.02, 1.83)	0.87 (0.56, 1.34)	
Respondent birth setting			< 0.001
Public institution	Ref	Ref	
Private institution	1.3 (0.27, 6.42)	0.92 (0.58, 1.45)	
Non-institutional with trained attendant		2.19 (0.77, 6.23)	
Non-institutional with traditional attendant	1.81 (0.52, 6.32)	1.78 (1.35, 2.34)	
Non-institutional with no attendant	1.25 (0.34, 4.64)	1.93 (1.41, 2.64)	

*p value represents significance of Type 3 analysis of effects from multinomial logistic regression model

Studies in Ethiopia have also found Somalis with reduced odds of full vaccination, potentially indicating a more universal risk for non-vaccination among migrants and refugees in East African countries (Lakew et al. 2015; Mohamud et al. 2014). In Ethiopia, Somali migrant communities tend to be pastoralist and have benefited from targeted immunization services, which could be a successful strategy to improve vaccination outcomes for Somalis in Kenya as well (Mohamud et al. 2014). Somalis' increased odds of non- and under-vaccination may also reflect systematic bias against a minority group at the societal, institutional and individual levels, which may result in reduced access and differing health-seeking behaviors that together may decrease vaccination. Increased efforts are warranted to improve Somalis' vaccination status, perhaps through tailored educational campaigns or localized interventions to increase coverage.

Higher socioeconomic status (SES) as measured by wealth index generally leads to improved uptake and better vaccination coverage. We observed wealth index to have an inverse trend for odds of both under- and non-vaccination for Kenyan non-Somalis only, with richer quintiles having reduced odds of under- and non-vaccination and the poorest quintile with significantly increased odds of non-vaccination and under-vaccination compared to the middle income, aligned with the findings of previous studies (Lakew et al. 2015; Rossi 2015). The fact that the interaction analysis revealed no impact of wealth index on full vaccination among Somalis again may point to systemic barriers to vaccination which indiscriminately cut across all socioeconomic levels of the Somali population. While programmatic efforts and resources focused on poorer sectors of Kenyan society may improve full vaccination outcomes among non-Somalis, these efforts may be less

Table 4 Multinomial logistic interaction model for fully vaccinated status versus not fully vaccinated status (i.e., non- and under-vaccinated combined) for Kenyan children aged 12–23 months, Kenya Demographic and Health Survey IV, 2014

Interaction covariates	Somalis OR (95% CI)	Non-Somalis OR (95% CI)	Interaction p value[*]
Female versus male	1.40 (0.85, 2.30)	1.1 (0.94, 1.30)	0.373
Rural versus urban	0.41 (0.19, 0.91)	1.2 (0.97, 1.47)	0.011
Wealth Index			0.003
Poorest	0.33 (0.06, 1.88)	0.48 (0.37, 0.62)	
Poorer	0.14 (0.02, 1.16)	0.91 (0.69, 1.20)	
Middle	Ref	Ref	
Richer	0.12 (0.02, 0.89)	1.24 (0.89, 1.72)	
Richest	0.87 (0.09, 8.13)	1.16 (0.80, 1.68)	
Birth setting			< 0.001
Public institution	Ref	Ref	
Private institution	0.69 (0.15, 3.19)	1.02 (0.76, 1.39)	
Non-institutional with no attendant	0.00 (0.00, 0.00)	0.53 (0.42, 0.67)	
Non-institutional with traditional attendant	0.40 (0.20, 0.80)	0.49 (0.39, 0.61)	
Non-institutional with trained attendant	3.85 (0.40, 36.93)	0.36 (0.19, 0.67)	

*p value represents significance of interaction parameter for each predictor with Somali ethnicity from joint F test

likely to improve the situation for Somalis, necessitating more targeted interventions.

While religion on the whole was significantly associated with non- or under-vaccination, only Muslims showed significantly decreased odds of non-vaccination compared with Protestant/Other Christians, the reference group. The adjusted analysis included ethnicity, and perhaps after controlling for ethnicity, religion did not show as significant a relationship to vaccination status as has been reported in the literature because nearly 100% of the Somalis present in our sample were Muslim. These findings are aligned with those of a Nigerian study showing differences in vaccination status could be better explained by underlying sociodemographic factors instead of religious differences (Antai 2009).

Birth setting, particularly public institutional birth compared with home delivery, has consistently been shown to be associated with increased odds of complete vaccination in Kenya (Canavan et al. 2014). We found a significant relationship between birth setting and odds of non- and under-vaccination, especially for non-institutional births with a traditional attendant, and no attendant, which had increased odds of both non- and under-vaccination compared to the reference group of public institutions. This was one of the few predictors that demonstrated a consistent association across both Kenyan Somalis and non-Somalis. Perhaps those born in a non-institutional setting have reduced access to health professionals who would vaccinate the newborn or convey information to the mother about vaccinations regardless of ethnic group and may come from lower socioeconomic strata with reduced maternal education. Additionally, non-institutional births

lack behavior modeling for immunization, as mothers are not surrounded by other newborns receiving vaccines, as would be the case with institutional births (Byrne et al. 2016). Approximately 20% of the survey population analyzed in this study and nearly 60% of Kenyan Somalis had a non-institutional birth with a traditional birth attendant (TBA), concordant with existing literature that many Kenyans rely on TBAs despite their lack of formal medical training (Bucher et al. 2016; Byrne et al. 2016; Mason et al. 2015), although TBAs are known to promote immunization services in some sub-Saharan African countries (Ray and Salihu 2004; Temesgen et al. 2012). Given that TBAs are still preferred by many Kenyans, despite promotion by the Kenyan government to utilize skilled birth attendants or midwives instead, incorporating novel training to TBAs to provide information and facilitate mothers' receiving immunization services for their children may significantly improve vaccination outcomes (Byrne et al. 2016; Mason et al. 2015).

Research studies regarding vaccination have focused on binary indicators of vaccination: non-vaccinated versus under- or fully vaccinated, or fully vaccinated versus not fully vaccinated, but a research gap exists when characterizing predictors for under-vaccination. We found that nearly one-fifth of the study population received some, but not all, of their EPI vaccines and nearly a third of Somalis fell into the under-vaccinated category. Levels of measles vaccinations were particularly low, which confirms results from other studies in Kenya citing lagging levels of measles vaccination (Kawakatsu et al. 2015; Ministry of Public Health 2013; Onsomu et al. 2015) and indicates a

need to redouble efforts to vaccinate against measles, particularly among Somali minority groups.

Strengths and limitations

The study has several limitations. Vaccination status for children was based on mothers' recall if vaccination cards were not available, potentially introducing recall or social desirability bias with mothers over-reporting vaccination status. However, prior studies have reported that in countries lacking immunization cards or hard-copy records, maternal recall provides accurate population-level estimates of vaccine coverage, and provides a larger sample size than restricting the dataset those with vaccination cards (Valadez and Weld 1992). Kenya's North Eastern region was sampled without inclusion of variables permitting identification of an individual as a member or resident or the Dadaab refugee camp, which in turn limited our ability to determine whether Somalis sampled from this region were Kenyan or Refugees. The analytic decision to use the oldest child in households with > 1 child may also have introduced bias, as the vaccinating behaviors for eldest children may be different than for younger children. Additionally, because the DHS is a cross-sectional survey, inference about temporal associations between variables is limited.

The study has several strengths. The DHS, a large, cross-sectional nationally representative dataset, provided a large sample size, affording the opportunity to test associations with sufficient statistical power. Survey methodology was used to account for the data's sampling design, permitting the calculation of unbiased estimates. This is the first study to the authors' knowledge that characterizes predictors of risk for under- and non-vaccination among Kenyans using the 2014 DHS dataset and examines how those associations change for Kenyans of Somali ethnicity.

Conclusions

Using a large, nationally representative sample from Kenya, we found that immunization uptake in Kenyan children fell well short of the Ministry of Health's and Sustainable Development Goal vaccination targets, with coverage levels often too low to interrupt transmission of disease. The Somali ethnic group had noticeably increased odds of under- and non-vaccination, which may indicate the presence of systemic discrimination and differential or reduced health-seeking behaviors. Additionally, non-institutional births with traditional or no attendant decreased the odds of full vaccination among both Somalis and non-Somalis. The Kenyan government may wish to devote additional attention to providing educational resources and

training to TBAs to improve rates of vaccination among the large proportion of those surveyed who rely on them for non-institutional birthing support, especially given the large proportion of Somalis who rely on TBAs. Additionally, efforts to vaccinate Somalis and integrate migrant and ethnic communities into the health system can have beneficial impacts on population-level immunity for Kenyans as a whole.

Compliance with ethical standards

Conflict of interest The authors have no potential, perceived, or real conflicts of interest relevant to this article to disclose. NBM wrote the first draft of the article.

Ethical approval This study was exempt from ethical approval because it was limited to the publicly available Demographic and Health Surveys (DHS) dataset which contained no personally identifiable information beyond birthdates.

Informed consent All participants provided informed consent before being enrolled in the DHS.

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